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**DØ**

## **A Scintillating Fiber Detector for the DØ Upgrade**

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## A SCINTILLATING FIBER DETECTOR FOR THE DØ UPGRADE

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### ABSTRACT

In the Step 1 version of the DØ upgrade, the inner vertex chamber will be replaced by a system of silicon microstrips surrounded by a scintillating fiber detector. Details of the detector design and status of R&D and construction programs for the detector are presented. Progress on the upcoming large-scale cosmic ray test at Fermilab is also reported.

### 1. Introduction

In order to guarantee that the D0 experiment remains competitive and fully capable of exploiting the physics opportunities at the Tevatron during the next decade, D0 has embarked upon a series of major detector upgrades. In the fully upgraded D0, the current central tracking system will be replaced with a system of silicon-strip detectors surrounded by a tracking detector consisting of over 80,000 scintillating fibers. Both the silicon and fiber trackers will be inside a large superconducting solenoid which will provide a 2T magnetic field.

The D0 upgrade will take place in two stages. In the "Step 1" upgrade, planned for late 1995, the D0 inner vertex chamber will be replaced by a smaller combination of silicon and fiber detectors. A quarter-section view of the Step 1 detector is shown in Fig. 1. The Step 1 fiber tracker will contain 3 concentric cylinders of 1.8 m length located at radii of 12.5, 14.5 and 16.5 cm. Each cylinder will support a "superlayer" of scintillating fibers made up of 3 doublets of fiber layers oriented in the axial and  $\pm 2^\circ$  stereo directions, giving a total of approximately 18,000 fibers. Each scintillating fiber is coupled to a clear fiber of the same construction, which pipes the light to the photodetector. The photodetector of choice for D0 is the Visible Light Photon Counter (VLPC), a solid state device capable of single photon counting with high efficiency (70 – 90%) and speed.

### 2. Status of Detector Development

The basic element of this detector is, of course, the scintillating optical fiber. In D0, the active fibers will have a diameter of 835 microns and will be constructed of a polystyrene core surrounded by a thin ( $\leq 30$  micron) acrylic cladding. The techniques necessary for making high-quality fiber are well understood, and commercial firms can manufacture large quantities of fiber with dimensional control on the diameter of  $\sigma = 2\%$  RMS in the diameter. In addition, these fibers are made with high purity which gives them long attenuation lengths (11–12 meters) for the wavelengths of interest. To make the fibers sensitive to minimum ionizing parti-

cles, they are doped with a 1% concentration of p-terphenyl and a much smaller concentration of 3-hydroxyflavone. The scintillation light is produced in a 3-step process, resulting in yellow-green light with a peak wavelength of 530 nm.

Before being placed on their support cylinders, individual fibers are glued into doublet ribbons, 128 fibers wide with a center-to-center spacing of 870 microns. Singlet ribbons are made by placing 128 fibers into precision grooves of the correct spacing, after which a thin fiberglass sheet, followed by a thin mylar sheet, are laid over the fibers. The whole ensemble is glued together to make a single layer sandwich. The final doublet ribbon is made by gluing two singlet layers together, maintaining a 1/2 fiber diameter space offset between the two. Many 128-fiber wide ribbons have been made and the variation in center-to-center spacing across the ribbons can be controlled to below 10 microns.

The three support cylinders for Step 1 will consist of a honeycomb core covered by a carbon-fiber skin. Two such cylinders have been manufactured and measured. Except for the extreme ends of the cylinder, which were slightly deformed by end rings, the radius is constant to within about 150 microns. With the anticipated ribbon width of 128 fibers, this precision is already well within the tolerance imposed by the fiber tracker's requirements for position resolution.

Details and status of the VLPC are presented in another paper<sup>2</sup> and won't be covered here. However, a great deal of progress has been made in the design of the cryogenics system necessary to maintain large numbers of VLPCs at their 6.5 K operating temperature. In the D0 design, 128 channels of VLPC (16 arrays of 8 channels each) are mounted in the bottom of a 25cm-long cylindrical container known as a "cassette". Light is brought to each VLPC pixel via clear waveguide fibers, which are coupled by an optical connector at the top of the cassette to the clear fibers coming from the active detector. A cold finger at the bottom of the cassette sits in a liquid helium volume while a layer of cold, gaseous helium surrounds the cassette and maintains the VLPCs at their operating temperature. A small cryostat for operating single cassettes is under construction, and the design of a full-size cryostat capable of supporting 24 cassettes is near completion.

### **3. Cosmic Ray Test**

An important milestone for D0 will be the operation of a  $\geq 3000$  channel cosmic ray test in early 1993. D0 has purchased 5000 channels of VLPC from Rockwell International. These devices will be packaged into cassettes, 24 of which will be used for the test. In the cosmic ray setup, a support cylinder will be partially covered by fiber superlayers both top and bottom, with a third, flat superlayer placed inside the cylinder volume. The cosmic ray test will utilize essentially all the components required by the final detector, from the construction of fiber superlayers,

to the operation of 3000 VLPCs, to the acquisition and analysis of the data.

#### 4. Simulation Studies

In parallel to the extensive R&D and engineering progress described above, a great deal of effort has gone into the simulation and study of detector performance. This analysis played an important role in the optimisation of the Step 1 design, where the results indicated that the choice of three fiber cylinders over two will enhance the robustness and the stand-alone capabilities of the detector. The stereo angle of  $2^\circ$  was chosen to minimize the number of "ghost" tracks while maintaining the detector's ability to determine track coordinates in the axial direction. The simulation studies have also shown how the Step 1 scintillating fiber tracker will play an important role in helping DØ exploit the future physics opportunities at the Tevatron. While the silicon system provides excellent position resolution in the  $r - \phi$  plane, the addition of the scintillating fiber information greatly improves the ratio of signal to background for the identification of isolated leptons and for the tagging of b-quark jets resulting from decays of the top quark.

#### 5. Summary

The planned upgrade of the DØ detector includes the implementation of a tracking detector based on scintillating fibers with VLPC readout. The design and engineering of several of the major components of a fiber tracker is well understood. The operation of an approximately 3000 channel cosmic ray test early next year will provide an important test of a prototype full-scale fiber tracking system.

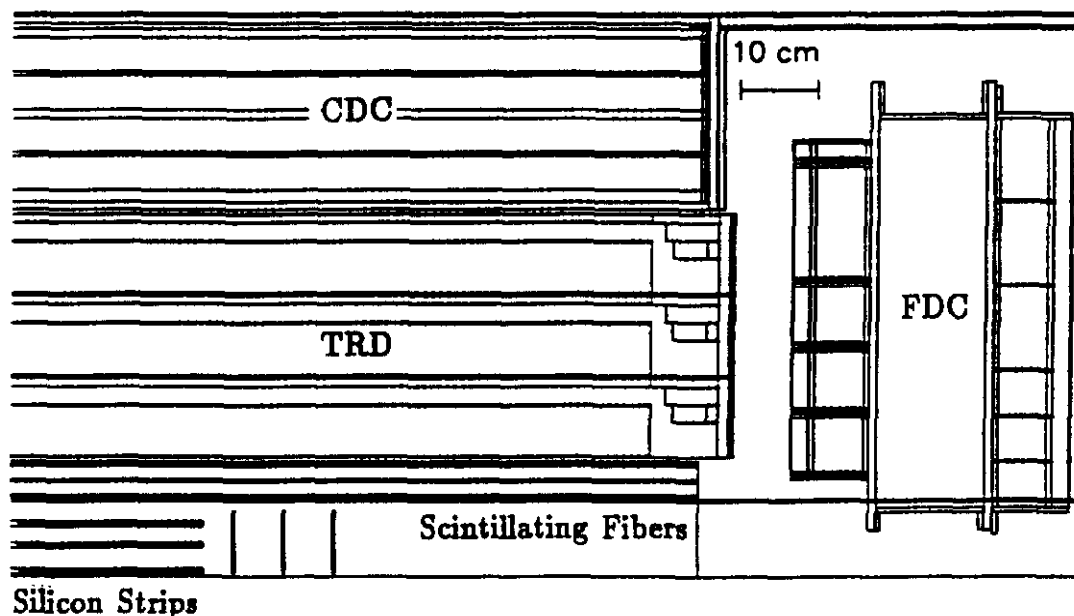


Fig. 1 Quarter-section view of the DØ Step 1 Tracking system